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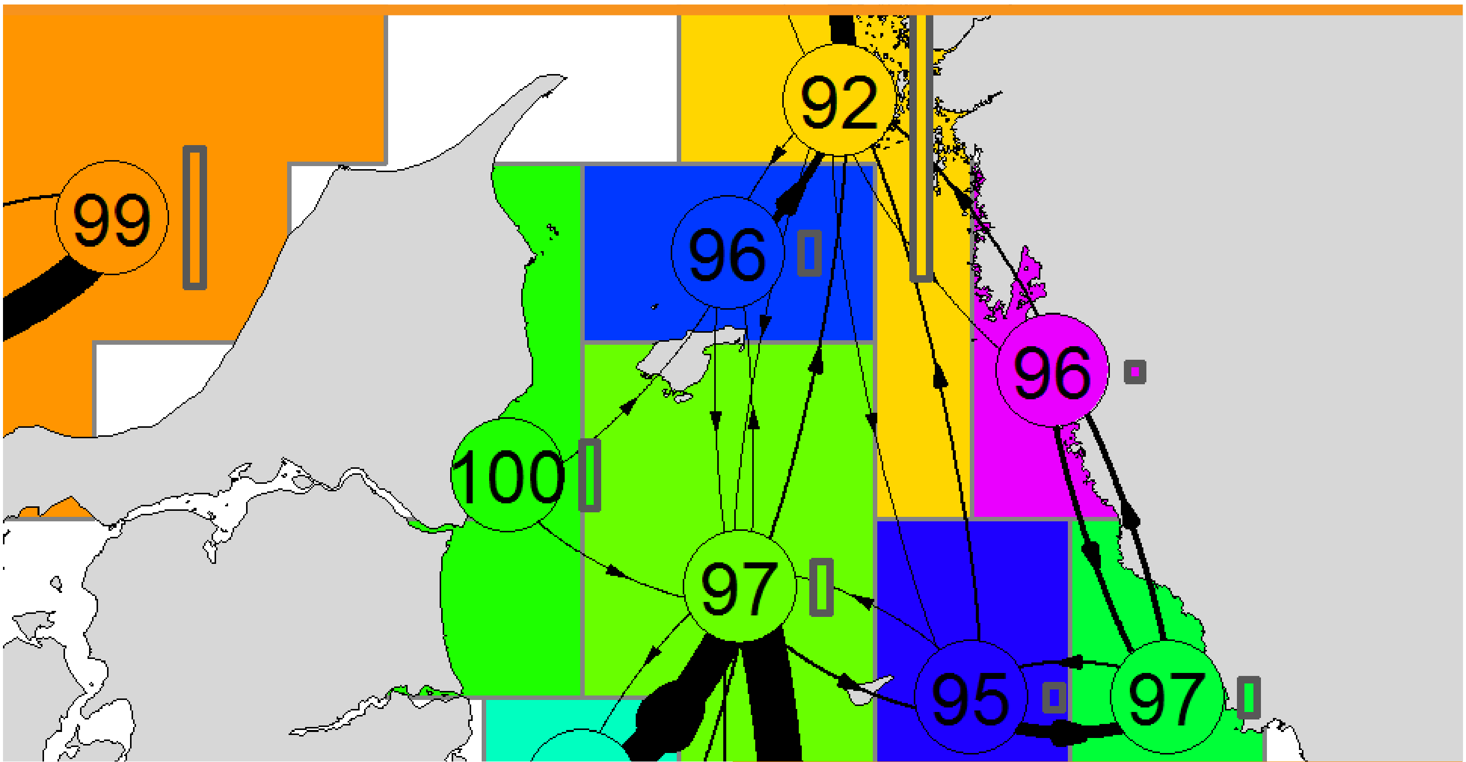

DTU Aqua report no. 335a-2018

By Flemming Thorbjørn Hansen
and Asbjørn Christensen

DTU Aqua
National Institute of Aquatic Resources

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Flemming Thorbjørn Hansen and Asbjørn Christensen

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Contents

1 Introduction

This appendix 1 is an appendix to the report “SRA Case Study for Kattegat and Øresund”. Section 2 in the appendix describes the methodology and criteria applied for selecting the marine invasive species considered in the case study. Section 3 gives an overview of the various traits represented by the selected species. In general, the quality and quantity of data and information on species life history varies considerable between species and originates from a large variety of sources. The traits presented here should be regarded as a best estimate so far, some of which very likely will be modified in future analysis when new and better data is provided.

Out of a gross list of 84 marine invasive species identified for the Kattegat and Øresund region, 23 species were selected for the case study. The species lists are presented in tables 1 and 2 in the end of the appendix.

2 Review of existing Marine Invasive Species lists for the Kattegat and Øresund region

2.1 Data availability

A number of references exist that compile lists of marine invasive species for the Kattegat and Øresund region, e.g.:

- HELCOM/OSPAR Ballast Water Exemptions Decision support tool[1]
- Danish Nature Agency[2]
- AQUANIS[3]

While lists on marine invasive species including the Kattegat area are available from both HELCOM and OSPAR commissions for the North Sea and the Baltic Sea respectively, both commissions cover large areas beyond the extent of the Kattegat and Øresund region. As a joint effort, the Ballast Water Exemptions Decision Support Tool is available for querying these lists to extract species potentially subject to ballast water mediated transport, and specifically, a list can be extracted for Kattegat as an overlapping area between the two commissions. This list covering target species for the Kattegat area has been chosen as the primary list for of species for this review and comprise **38 species**.

As a supplement to this list, species that occur on lists produced for the Danish Nature Agency (Jensen 2013) adds another **7 species** (one of these is a group of teleosts comprising un-specified species of goby's.)

In addition, data from the AQUANIS database on aquatic marine invasive and cryptogenic species maintained by Klaipeda University in Lithuania have been included adding another **39 species**. These species were identified by querying the database for species found in the North Sea and Baltic region, associated with "ballast water" or "ballast water tank sediments", and by excluding species, which are purely freshwater species with no salinity tolerance.

Thus, a total number of 84 species were identified for further examination. This gross list is shown in in table 2.

2.2 Selection criterion

Of the 84 species listed in table 2 the species that met at least one of the criteria listed below were not considered for the SRA case study. These criteria include:

1. Species with the entire life cycle in the water column
2. Species that are already fully established in the Kattegat and Øresund region.
3. Species with no or very limited salinity tolerance < 10 PSU.
4. Macro algae and macrophytes.

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[1] HELCOM/OSPAR Ballast Water Exemptions Decision support tool (http://jointbwmexemptions.org)

[2] Jensen K 2013 "Selection of target species for risk assessment of danish ports in connection with the international convention for the control and management of ships' ballast water and sediments". Report for the Danish Nature Agency

[3] http://www.corpi.ku.lt/databases/index.php/aquanis/

Ad 1) Species with the entire life cycle in the water column (e.g. pelagic copepods, pelagic fish, pelagic phytoplankton, jellyfish etc.) are not expected to be a limiting factor for the extent and delineation of an SRA in Kattegat and Øresund compared to species with short pelagic life stages in the order of days or weeks.

Ad 2) Species already introduced to the Kattegat and Øresund region and considered fully established in all suitable habitats throughout the study area, are not a concern to the BWMC.

Ad 3) Freshwater species and species that do not tolerate salinities above 10 PSU are not expected to sur-vive in Kattegat and Øresund region except in local areas receiving freshwater from major rivers.

Ad 4) Most macro algae and macrophytes have limited (~ few meters) dispersal capability of seeds and spores. Shredded thallus however may drift in many month and over vast distances (>100s of km's). This long distance dispersal of thallus (also referred to as "rafting") is unlikely to be a limiting factor for identify-ing well-connected areas and dispersal barriers in the at Kattegat and Øresund region.

The resulting list comprising 23 species including literature data and/or estimates on biological traits are shown in table 1.The individual traits are reviewed in more detail below.

3 Biological traits review

3.1 Pelagic larvae duration (PLD)

Data on the pelagic larvae durations (PLD) was found in literature and databases for all 23 species representing a large range of values from less than 1 day and up to 120 days, and reported PLD values for each species are typically reported within a given range. While PLD in general is critical to the extent to which species disperse within a region, especially short PLD of hours or a few days will be a limiting factor for single generation dispersal in an area of the size of Kattegat and Øresund (~ 250x150 km's). Approximately 50 % of the species have mean PLDs between 20 and 50 days. Approximately 25 % of the species have a mean PLD of less than or equal to 10 days, three of these have mean PLD's of 1 day or less. Frequencies of reported minimum and maximum PLD values for the 23 species are shown in Figure 1.

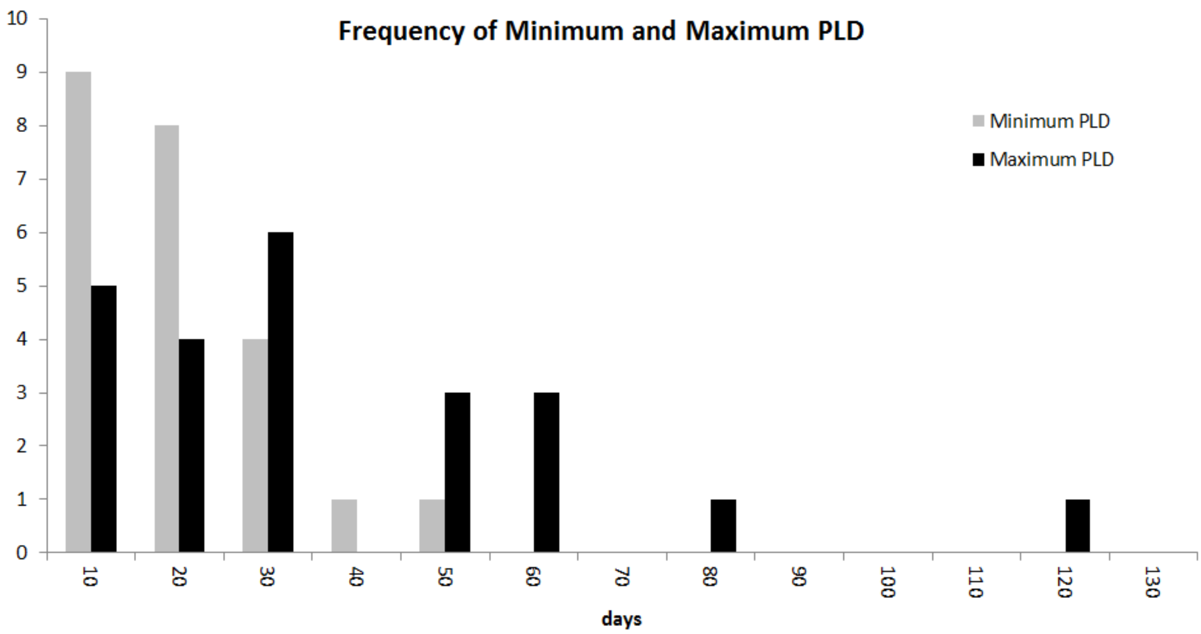

Figure 1. Frequencies of reported minimum and maximum PLD values for the 23 species included in the case study.

3.2 Generations per year

Of the 23 species included in the case study 18 species are described in the literature and databases as having one generation per year (Figure 2). Another 3 species are described as having more than on generation per year. The number of generations per year for these 3 species were estimated based on available information on maturation time (or time to first reproduction), PLD and the expected length of spawning period. The remaining 2 species require 2 years to reach maturity. In the case study the number of generations expected per year is important when trying to evaluate the dispersal potential of a marine invasive species within a given time period, e.g. 5 year corresponding to the exemption period. The more generations the larger the likelihood that an organisms may disperse to other parts of the region given the availability of required substrate and/or habitat via stepping stone dispersal.

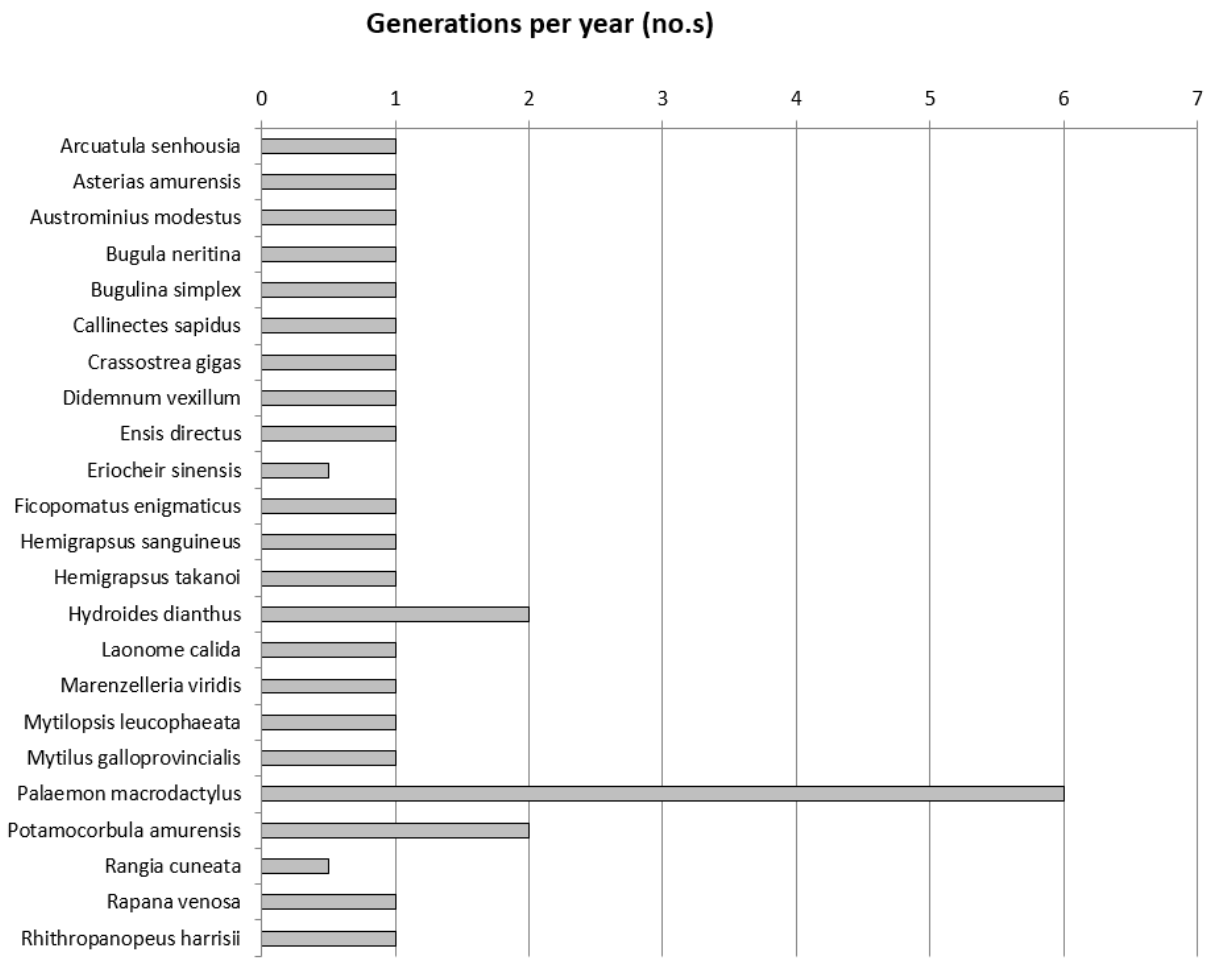

Figure 2. Estimated number of generations per year for the 23 species included in the case study.

3.3 Spawning period

The expected spawning season for each species were estimated based on available information reported from its native range and/or reported from comparable environments in areas outside its native range (Figure 3 and Figure 4). All of the 23 species are expected to spawn in spring, summer and/or autumn seasons. Only 4 species are expected to initiate their spawning in March or April, while 21 of the 23 species are expected to spawn during the month of July. The initiation and duration of spawning seasons for many species are determined by the development in water temperature but this was not considered explicitly in the larval dispersal modelling and connectivity analysis in the current study. For most species the relationship between temperature and the onset and duration of spawning season is unknown.

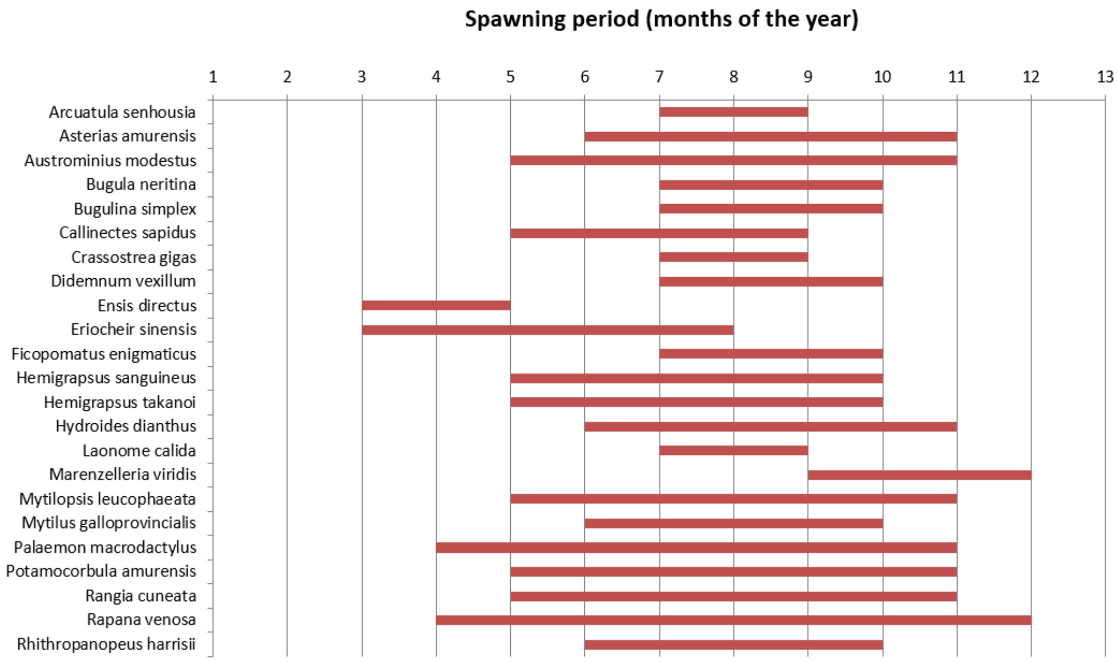

Figure 3. Expected spawning period of the year for the 23 species included in the case study.

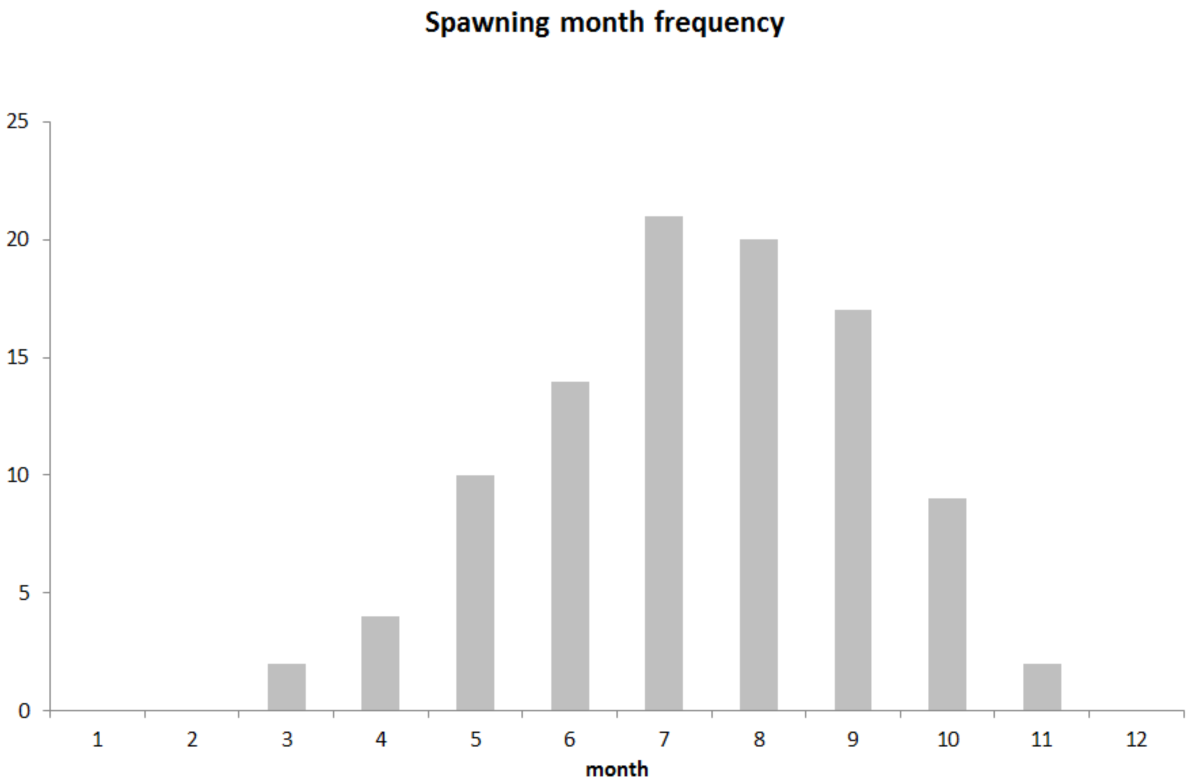

Figure 4. Number of species (out of 23 species included in the case study) expected to spawn each month.

3.4 Temperature tolerance for larvae

Data on larval temperature tolerance was retrieved from available literature and databases. Some data refer explicitly to larval survival tolerance limits, while other data refer to temperature ranges for reproduction, or temperature ranges required by the population as a whole. Because these criteria may not be directly comparable and to various degree relate specifically to larval temperature tolerance, data on temperature tolerance is not used explicitly in the larval dispersal modelling in the case study, but only considered as part of the interpretation of dispersal modeling results and the connectivity analysis.

Of the 23 species, 16 species has a minimum temperature tolerance (or threshold for reproduction) at temperatures of 15 degrees Celsius or less. Another 4 species requires minimum temperatures between 17 and 22.5. No data was found for the remaining 3 species.

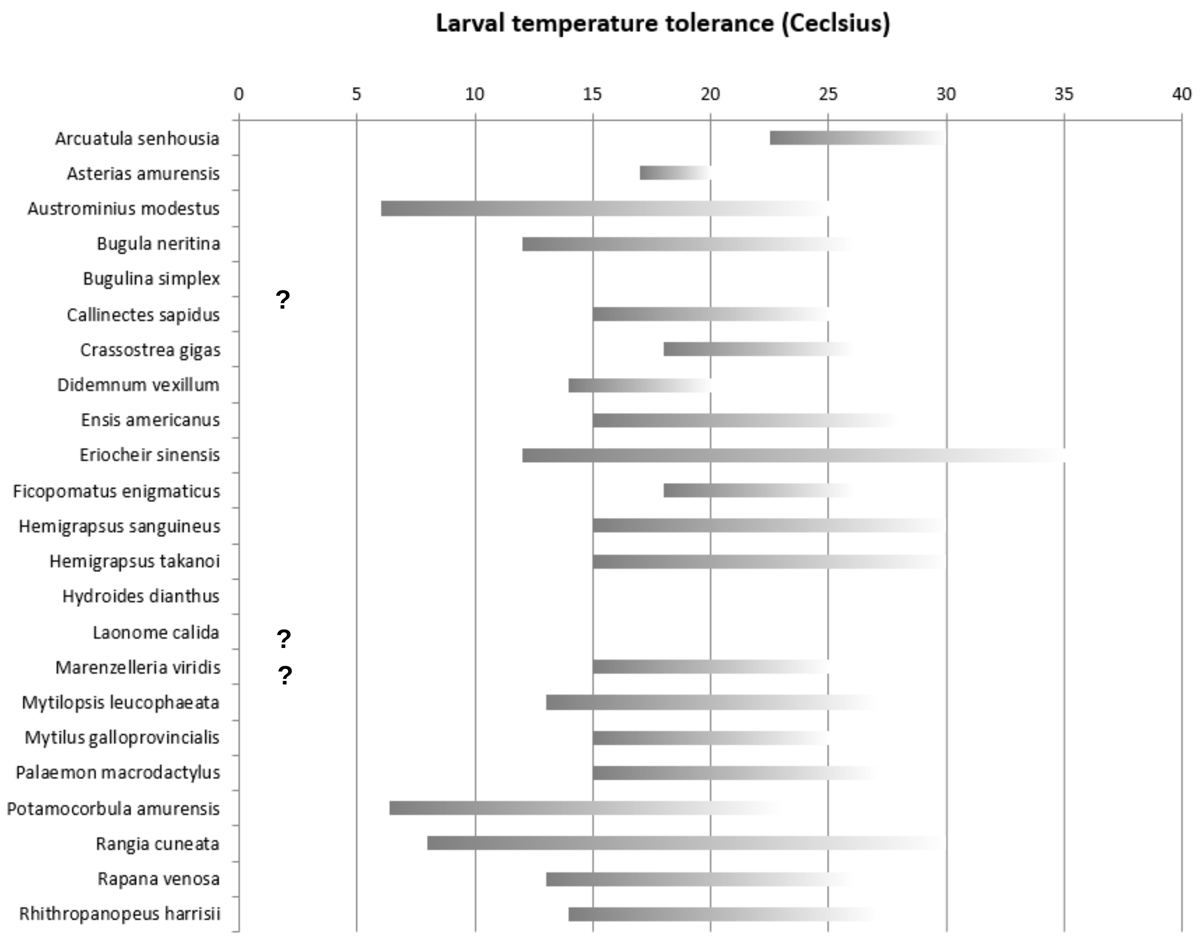

Figure 5. Larval temperature tolerance lower limit for the 23 species included in the case study.

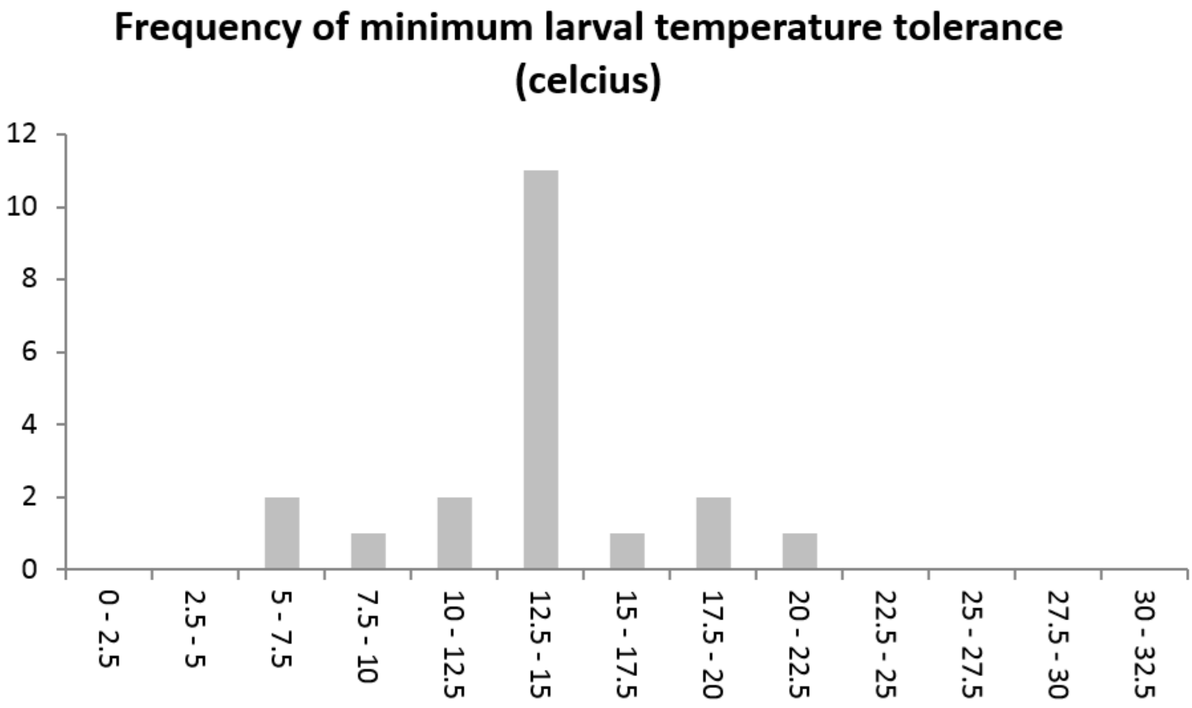

Figure 6. Frequency distribution of minimum larval temperature tolerance for the 23 species included in the case study.

3.5 Salinity tolerance for larvae

Data on larval salinity tolerance for individual species were derived from data expressing the larval tolerance in terms of survival or in terms of minimum and maximum salinities for reproductions. In either case we interpreted these data as the salinity ranges at which larvae can successfully develop through all larval phases and settle onto a suitable substrate. Simulated larvae exposed to salinity outside the salinity tolerance range were excluded from the connectivity analysis.

Of the 23 species the larval stages of 20 species tolerate salinity of 30 PSU or more (Figures 7, 8, and 9). For these species an upper threshold for larval salinity was not included in the connectivity analysis. For 3 species upper salinity thresholds between 20 and 27 PSU were applied. The larval salinity tolerance to lower salinity levels show much more variable tolerances some species tolerating very brackish conditions while other species are more intolerant. The distribution of the lower limits for larval salinity tolerance is approximately randomly distributed between 0 and 30 PSU (Figure 9).

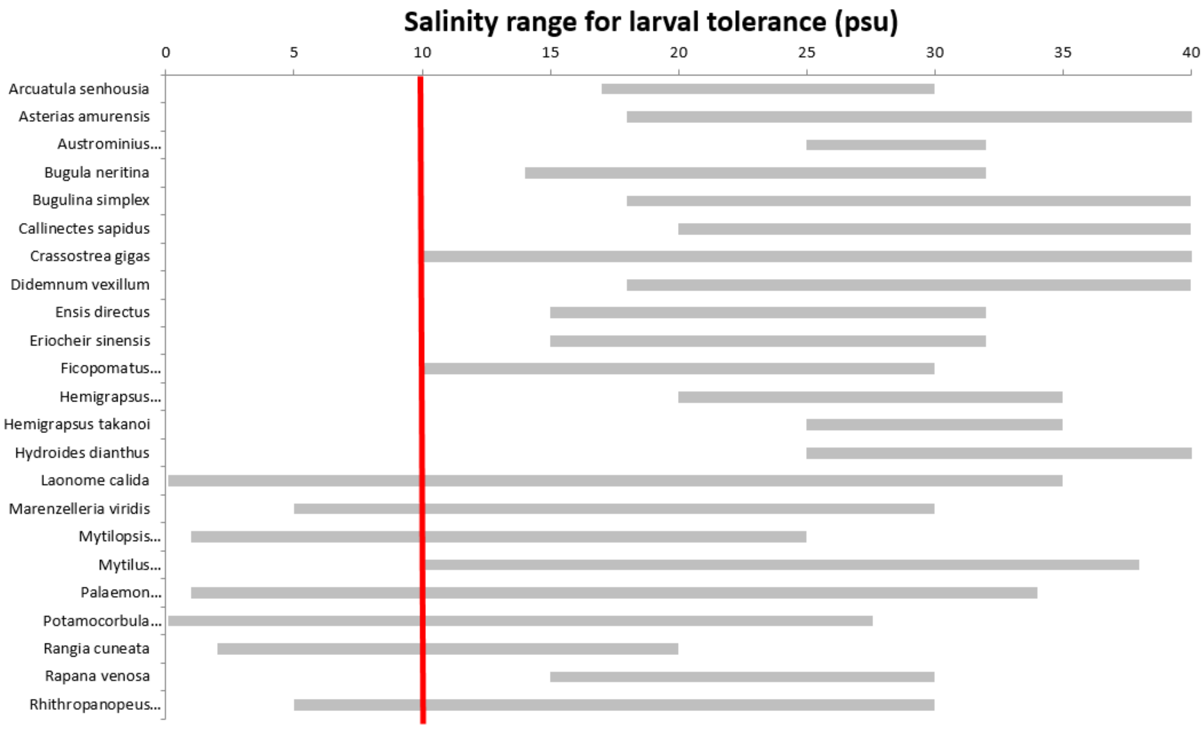

Figure 7. Larval salinity tolerance ranges for the 23 species included in the case study. Red line indicates the approximate lower threshold for salinity range for Kattegat and Øresund.

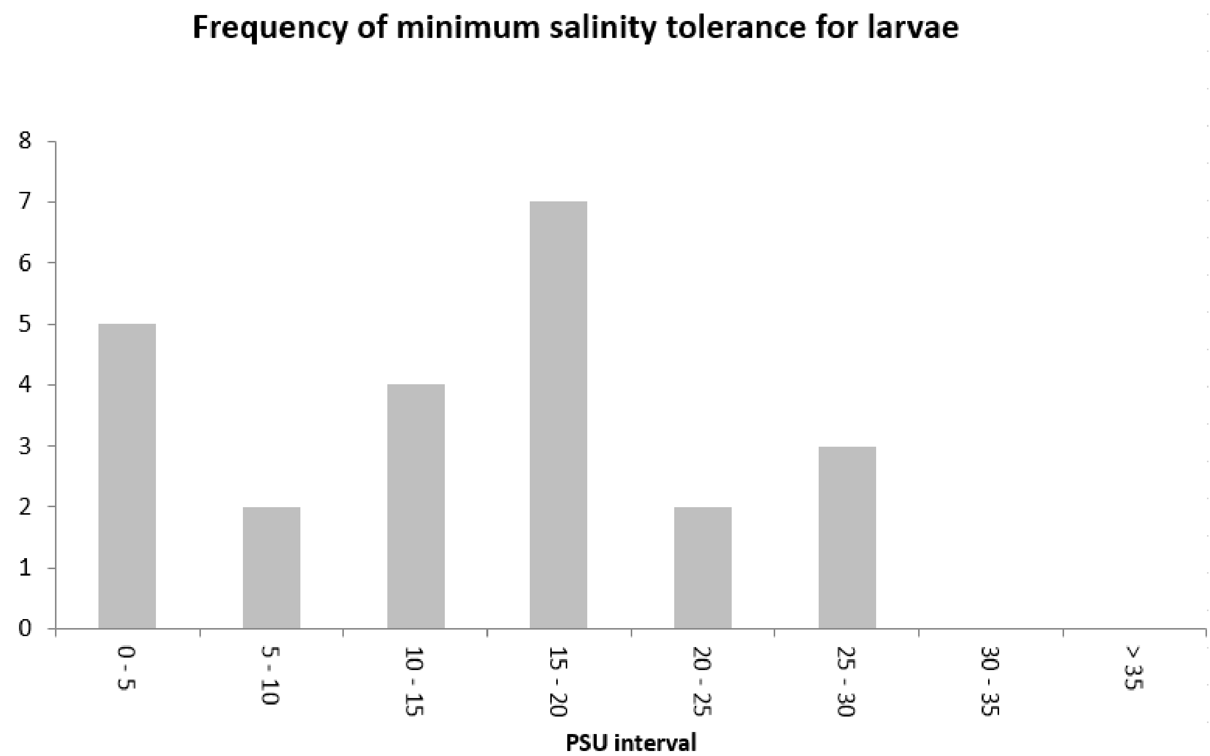

Figure 8. Frequency distribution of minimum larval salinity tolerance for the 23 species included in the case study.

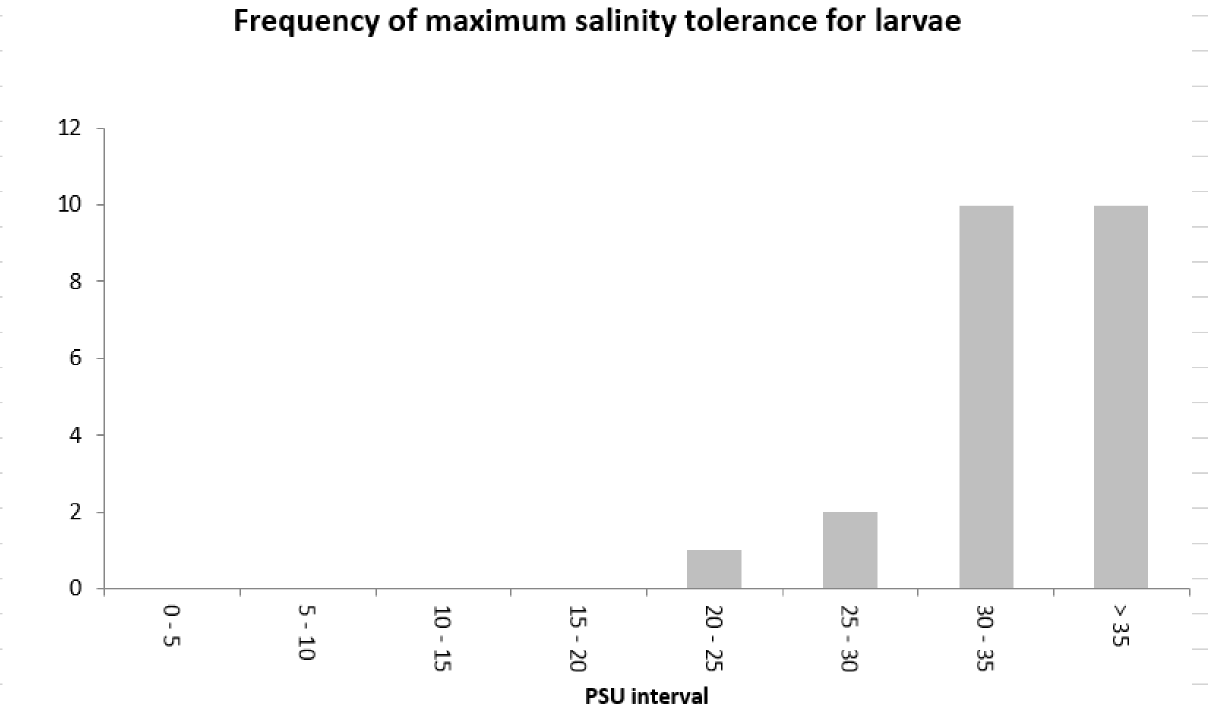

Figure 9. Frequency distribution of maximum larval salinity tolerance for the 23 species included in the case study.

3.6 Temperature tolerance for adult life stages

Data on lower temperature threshold for adult life stages were derived from databases and publication directly or by interpreting the minimum temperature conditions of the species native range or areas where introductions have occurred outside the native ranges. If populations have established in northern Europe minimum tolerance temperature for adult life stages were set to “0” if no specific data could be found. Of the 23 species included in the case study, 9 species were identified to have a minimum temperature tolerance above 0 degrees Celsius with a lower tolerance ranging between 1 and 5 degrees (Figure 10).

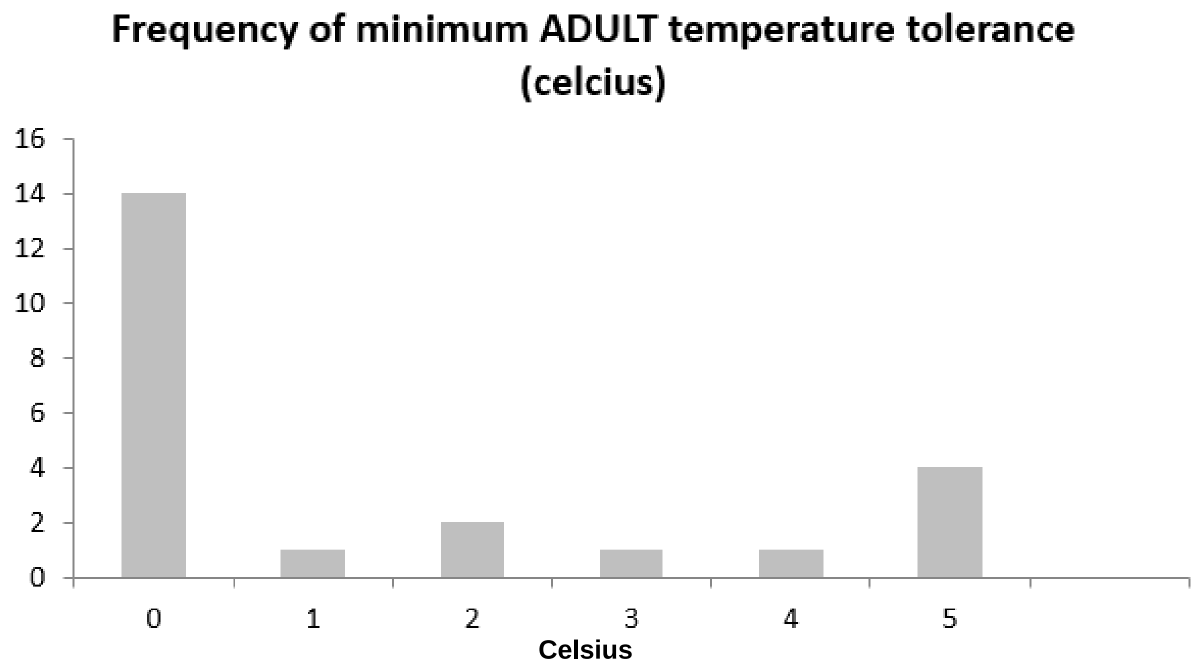

Figure 10. Frequency distribution of minimum temperature tolerance for adult life stages for the 23 species included in the case study.

3.7 Salinity tolerance for adult life stages

Data on known or expected salinity ranges tolerated by adult life stages found for all 23 species is shown in Figure 11. The data was used in the case study to classify the preferred habitat for each species according to whether salinity conditions are considered optimal or sub-optimal (see the main report).

Of the 23 species the adult life stages of 21 species tolerate salinity of 30 PSU or more (Figure 13). Two species require conditions that are more brackish. The salinity tolerance to lower salinity levels show much more variable tolerances some species tolerating very brackish conditions while other species are more intolerant (Figure 12).

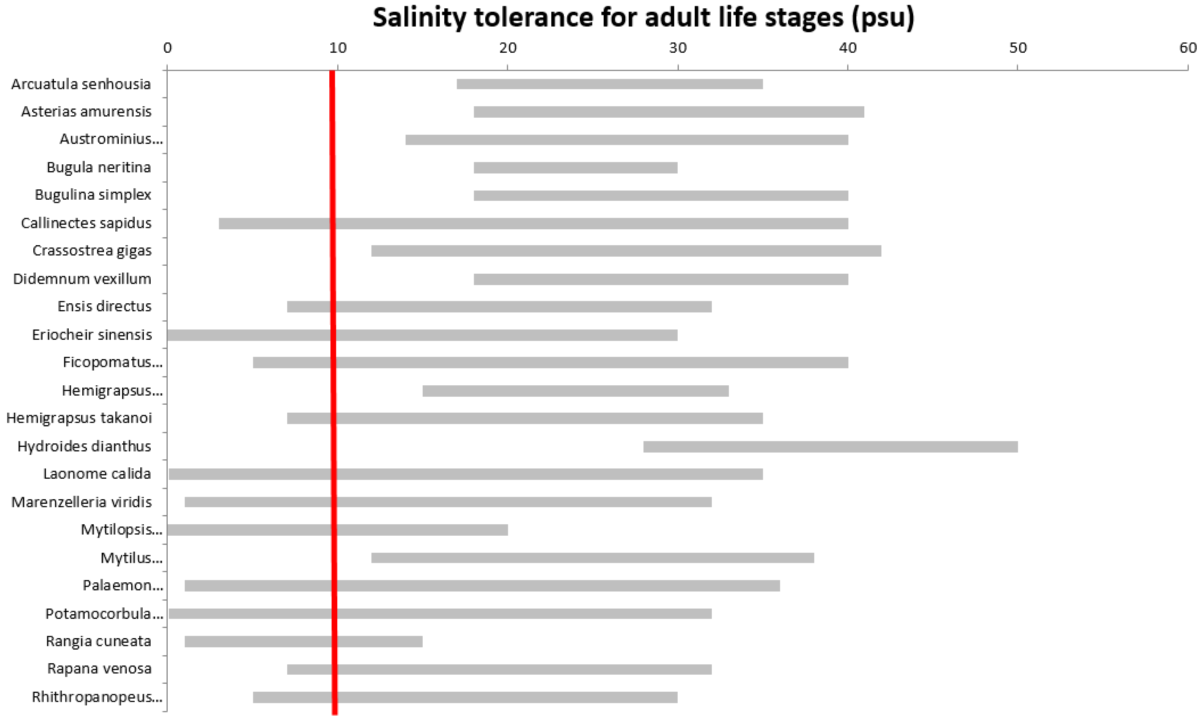

Figure 11. Salinity tolerance ranges of adult life stages for the 23 species included in the case study. Red line indicates the approximate lower threshold for salinity range for Kattegat and Øresund.

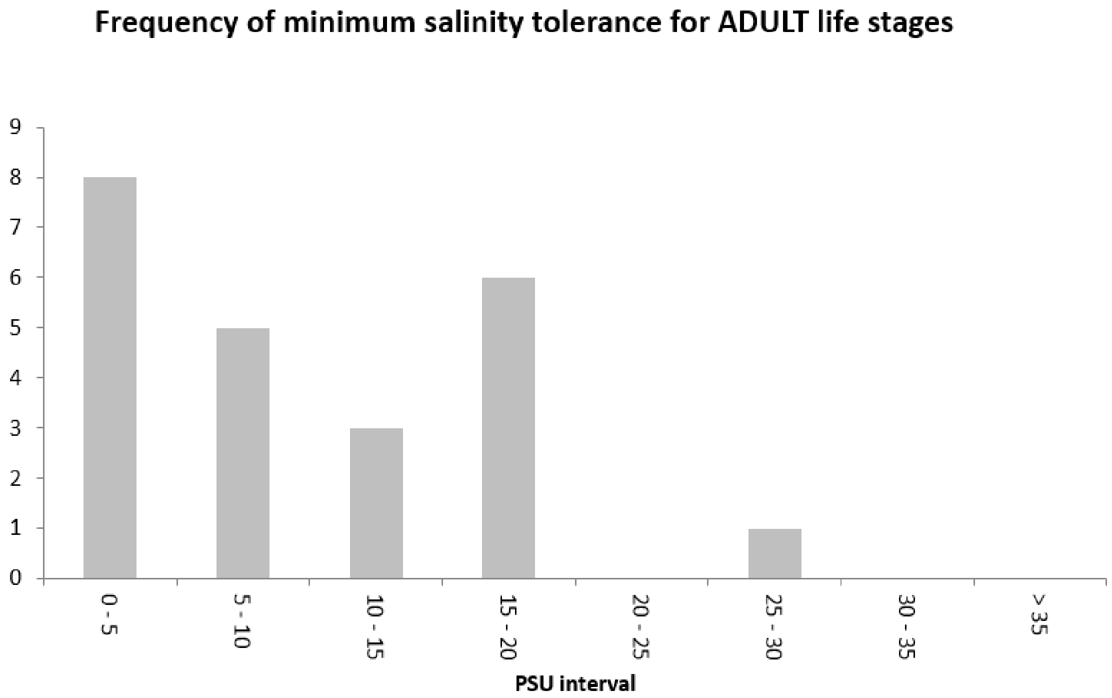

Figure 12. Frequencies of minimum salinity tolerance for adult life stages for the 23 species included in the case study.

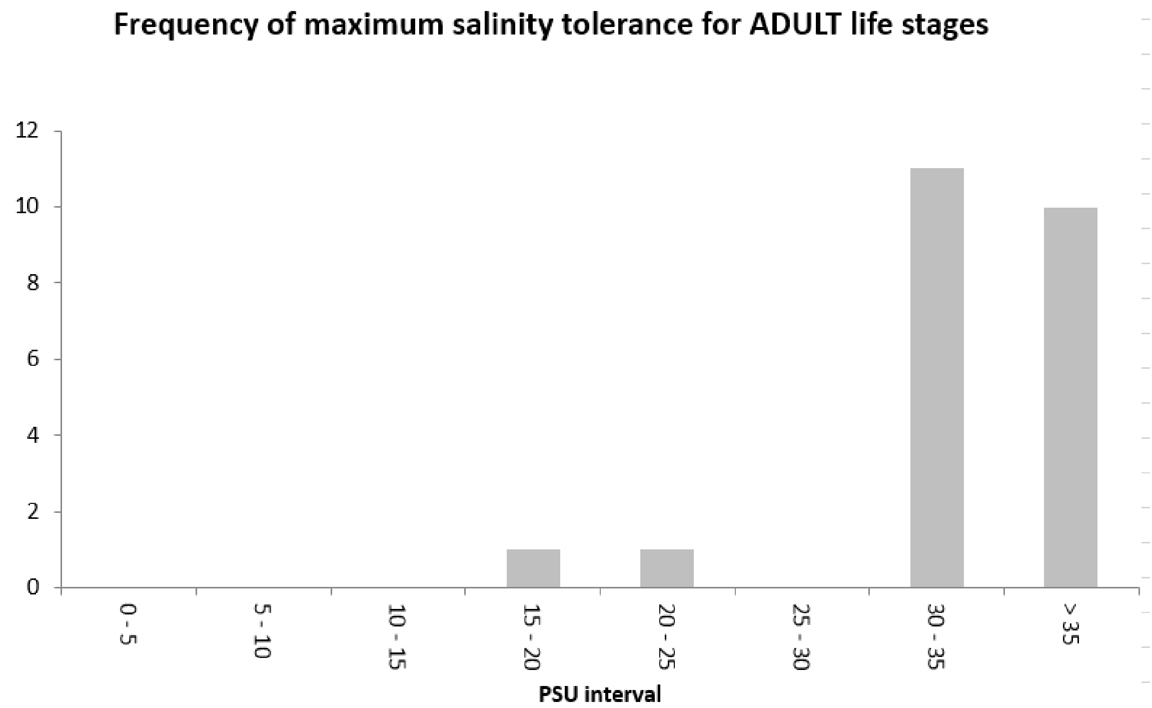

Figure 13. Frequencies of maximum salinity tolerance for adult life stages for the 23 species included in the case study.

3.8 Habitat

The habitat conditions here refer solely to the substrate type required by pelagic stages of a species to successfully settle, grow and eventually mature and produce new offspring. Here we crudely discriminate between “Mud”, “Sand” and “Hard” substrates and Vegetation (Figure 14). Data or descriptions of species habitat preferences were found in, or interpreted from, species databases and publications.

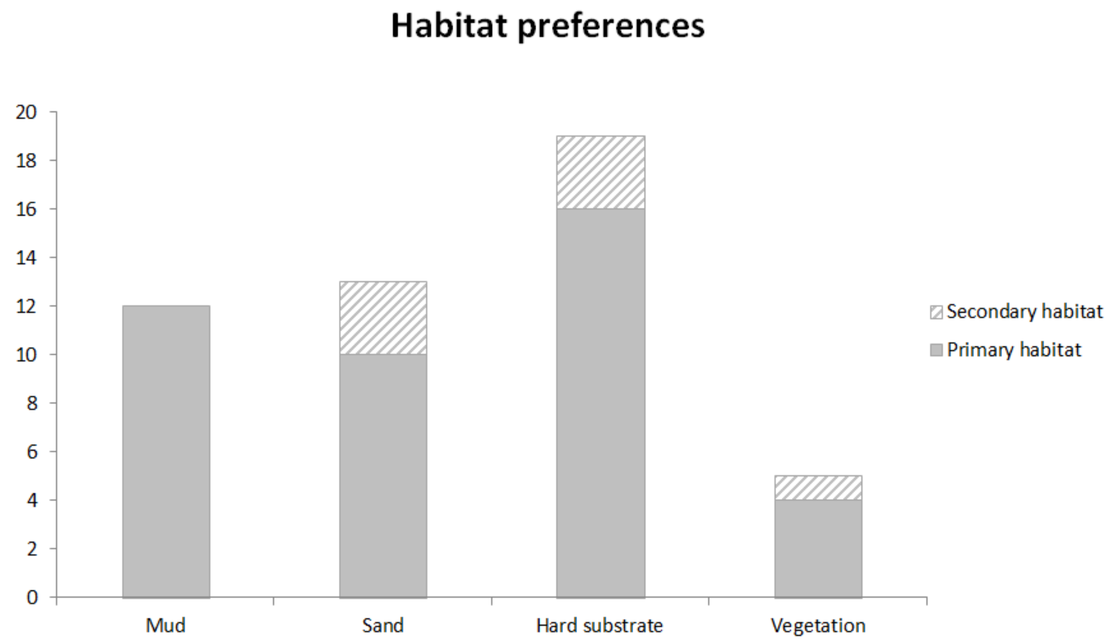

Figure 14. . Frequency distribution habitat preferences for the 23 species included in the case study, discriminating between three substrate classes (mud, sand and hard substrates) and vegetation. Each class is divided into “primary” and “secondary” habitats.

Of the 23 species included in the case study 19 species are associated with hard substrates (stone, rock, concrete, mussel-beds, mixed sediments etc.) while 12 and 13 may be found in muddy and sandy habitats respectively. Only 5 species have been associated with aquatic vegetation such as weed and seagrasses, however this should be evaluated critically. Because species found in rocky or stony, often tidal, habitats, these habitats are also areas where you will often find various types of vegetation. Species that may be associated with hard substrates may also attach and thrive on various types of vegetation surfaces. While substrate types are included explicitly in the larval dispersal modelling and connectivity analysis representing specific habitats, vegetated habitats are not included due to lack of data.

In addition to habitat substrate preferences, information on preferred depth distribution were included (Figure 15). The majority of species are known to have a maximum depth distribution between 0 and 40 meters depth, while only 4 species have a maximum depth distribution of 60 or deeper. Data on preferred maximum depth distribution were found for all species except *Laonome calidda.* Here a presumed maximum depth distribution of 40 meters was assumed.

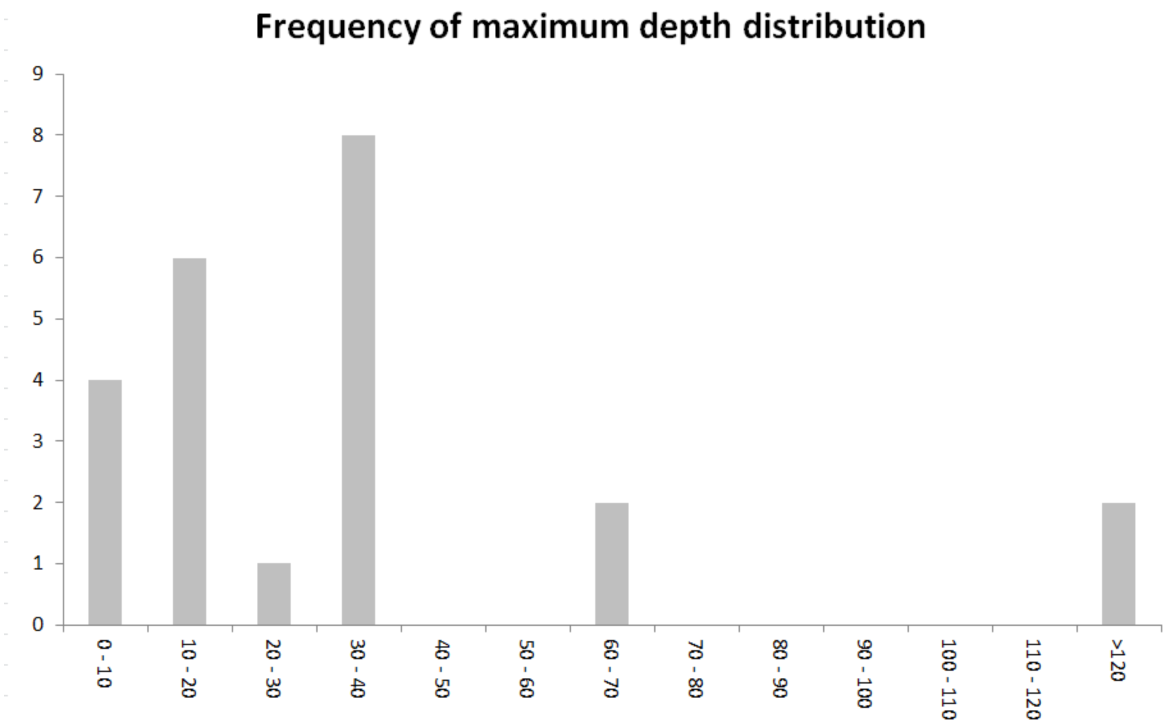

Figure 15. Number of species (out of the 23 species included in the case study) with a maximum depth distribution within each 10 meter depth interval.

Table 1. The table include the 23 selected species for dispersal simulation and connectivity analysis in the case study for Kattegat and Øresund. The presented life history traits and environmental tolerances are retrieved from the literature and/or databases either as explicitly reported values or inferred or estimated from species descriptions and reports. For details on individual parameters, see text. Values followed by a ' * ' are based on assumptions where no empirical data or species descriptions could not be found.

SPECIES	Taxon	PLD (min)	PLD (max)	Generations per year	Spawning start	Spawning end	Habitat Substrate	Habitat Depth	Temp. Min (Adult)	Temp. Max (Adult)	Salinity Min (Adult)	Salinity Max (Adult)	Temp. Min (Larvae)	Temp. Max (Larvae)	Salinity Min (Larvae)	Salinity Max (Larvae)
		days	days	no.s	month	month	type	m	C	C	PSU	PSU	C	C	PSU	PSU
Arcuatula senhousia	Mollusca	14	55	1	7	8	All	20	0	33	17	35	22.5	30	17	30
Asterias amurensis	Echinodermata	41	120	1	6	10	All	220	0	25	18	41	17	20	18	41
Austrominius modestus	Crustacea	10	15	1	5	10	Hard	5	0	26	14	40	6	25	25	32
Bugula neritina	Bryozoan	0.5	2	1	7	9	Hard	10	0	25	18	30	12	26	14	32
Bugulina simplex	Bryozoan	1	1	1	7	9	Hard	20	0	25	18	40	?	25	18	40
Callinectes sapidus	Crustacea	31	49	1	5	8	Mud, Sand	36	5	30	3	40	15	25	20	40
Crassostrea gigas	Mollusca	21	28	1	7	8	Hard	15	3	35	12	42	18	26	10	42
Didemnum vexillum	Tunicata	0.5	1	1	7	9	Hard	65	2	28	18	40	14	20	18	40
Ensis directus	Mollusca	14	21	1	3	4	Mud, Sand	12	0	26	7	32	15	28	15	32
Eriocheir sinensis	Crustacea	30	60	0.5	3	7	All	10	0	25	0	30	12	35	15	32
Ficopomatus enigmaticus	Annelida	20	25	1	7	9	hard	10	0	30	5	40	18	26	10	30
Hemigrapsus sanguineus	Crustacea	16	55	1	5	9	Sand, Hard	40	5	30	15	33	15	30	20	35
Hemigrapsus takanoi	Crustacea	30	30	1	5	9	All	20	0	20	7	35	15	30	25	35
Hydroides dianthus	Annelida	5	14	2	6	10	Hard	200	5	30	28	50	?	20	25	50
Laonome calida	Annelida	1	1.5	1*	7*	8*	All	40*	0	30	0.1	35	?	25	0.1	35
Marenzelleria viridis	Annelida	28	49	1	9	11	Mud	65	0	25	1	32	15	25	5	30
Mytilopsis leucophaeata	Mollusca	6	14	1	5	10	Hard	40	5	37	0	20	13	27	1	25
Mytilus galloprovincialis	Mollusca	14	28	1	6	9	Sand, Hard	40	0	31	12	38	15	25	10	38
Palaemon macrodactylus	Crustacea	15	20	6	4	10	All	40	2	26	1	36	15	27	1	34
Potamocorbula amurensis	Mollusca	14	21	2	5	10	All	30	0	30	0.1	32	6.4	23	0.1	27.6
Rangia cuneata	Mollusca	7	7	0.5	5	10	Mud, Sand	15	1	29	1	15	8	30	2	20
Rapana venosa	Mollusca	14	80	1	4	11	All	40	4	27	7	32	13	26	15	30
Rhithropanopeus harrisii	Crustacea	7	43	1	6	9	Hard	37	0	35	5	30	14	27	5	30

Table 2. Long list of 84 marine invasive species subject to ballast water mediated transport and which include species that have already been registered in the Kattegat and Øresund region or species that have not yet been registered but have been identified as potential marine invasive species in the region Kattegat and Øresund. Bold species names with grey background color are species included in the SRA Case Study for Kattegat and Øresund.

	SPECIES NAME	Included in Case Study?	SOURCE
1	*Acartia (Acanthacartia) tonsa*	No	AQUANIS
2	*Alexandrium acatenella*	No	HELCOM/OSPAR
3	*Ammothea hilgendorfi*	No	AQUANIS
4	*Amphibalanus improvisus*	No	AQUANIS
5	*Antithamnionella spirographidis*	No	AQUANIS
6	***Arcuatula senhousia***	**Yes**	HELCOM/OSPAR
7	***Asterias amurensis***	**Yes**	HELCOM/OSPAR
8	*Atyaephyra desmaresti*	No	AQUANIS
9	***Austrominius modestus***	**Yes**	AQUANIS
10	*Balanus amphitrite*	No	AQUANIS
11	*Beroe ovata*	No	Jensen 2013
12	***Bugula neritina***	**Yes**	AQUANIS
13	***Bugulina simplex***	**Yes**	AQUANIS
14	***Callinectes sapidus***	**Yes**	HELCOM/OSPAR
15	*Caprella mutica*	No	HELCOM/OSPAR
16	*Cercopagis pengoi*	No	HELCOM/OSPAR
17	*Chara connivens*	No	AQUANIS
18	*Chelicorophium curvispinum*	No	AQUANIS
19	*Codium fragile subsp. fragile*	No	AQUANIS
20	*Conchoderma auritum*	No	AQUANIS
21	*Corbicula fluminea*	No	HELCOM/OSPAR
22	*Coscinodiscus wailesii*	No	HELCOM/OSPAR
23	*Craspedacusta sowerbii*	No	AQUANIS
24	***Crassostrea gigas***	**Yes**	HELCOM/OSPAR
25	*Crepidula fornicata*	No	HELCOM/OSPAR
26	*Dasya baillouviana*	No	AQUANIS
27	*Dasysiphonia japonica*	No	AQUANIS
28	***Didemnum vexillum***	**Yes**	HELCOM/OSPAR
29	*Dikerogammarus villosus*	No	HELCOM/OSPAR
30	*Dinophysis sacculus*	No	HELCOM/OSPAR
31	*Dreissena bugensis*	No	HELCOM/OSPAR
32	*Dreissena polymorpha*	No	HELCOM/OSPAR
33	***Ensis americanus***	**Yes**	HELCOM/OSPAR
34	***Eriocheir sinensis***	**Yes**	Jensen 2013
35	*Evadne anonyx*	No	AQUANIS
36	*Fibrocapsa japonica*	No	HELCOM/OSPAR
37	***Ficopomatus enigmaticus***	**Yes**	HELCOM/OSPAR

	SPECIES NAME	Included in Case Study?	SOURCE
38	*Fucus evanescens*	No	AQUANIS
39	*Gammarus tigrinus*	No	HELCOM/OSPAR
40	*Goby species*	No	Jensen 2013
41	*Gonionemus vertens*	No	AQUANIS
42	*Gracilaria vermiculophylla*	No	HELCOM/OSPAR
43	*Grateloupia turuturu*	No	HELCOM/OSPAR
44	***Hemigrapsus sanguineus***	**Yes**	HELCOM/OSPAR
45	***Hemigrapsus takanoi***	**Yes**	HELCOM/OSPAR
46	*Hemimysis anomala*	No	HELCOM/OSPAR
47	***Hydroides dianthus***	**Yes**	HELCOM/OSPAR
48	*Hypania invalida*	No	AQUANIS
49	*Ianiropsis serricaudis*	No	AQUANIS
50	*Incisocalliope aestuarius*	No	AQUANIS
51	*Jassa marmorata*	No	AQUANIS
52	*Karenia mikimotoi*	No	HELCOM/OSPAR
53	***Laonome calida***	**Yes**	AQUANIS
54	*Marenzelleria neglecta*	No	HELCOM/OSPAR
55	***Marenzelleria viridis***	**Yes**	AQUANIS
56	*Melita nitida*	No	AQUANIS
57	*Mnemiopsis leidyi*	No	Jensen 2013
58	***Mytilopsis leucophaeata***	**Yes**	HELCOM/OSPAR
59	***Mytilus galloprovincialis***	**Yes**	HELCOM/OSPAR
60	*Nemopsis bachei*	No	AQUANIS
61	*Neogobius fluviatilis*	No	AQUANIS
62	*Neogobius melanostomus*	No	HELCOM/OSPAR
63	*Obesogammarus crassus*	No	AQUANIS
64	*Odontella sinensis*	No	AQUANIS
65	***Palaemon macrodactylus***	**Yes**	HELCOM/OSPAR
66	*Paralithodes camtschaticus*	No	Jensen 2013
67	*Paranais frici*	No	AQUANIS
68	*Pfiesteria piscicida*	No	HELCOM/OSPAR
69	*Pontogammarus robustoides*	No	AQUANIS
70	***Potamocorbula amurensis***	**Yes**	HELCOM/OSPAR
71	*Potamopyrgus antipodarum*	No	AQUANIS
72	*Proasellus coxalis*	No	AQUANIS
73	*Prorocentrum cordatum*	No	AQUANIS
74	*Pseudochattonella verruculosa*	No	HELCOM/OSPAR
75	***Rangia cuneata***	**Yes**	HELCOM/OSPAR
76	***Rapana venosa***	**Yes**	HELCOM/OSPAR
77	***Rhithropanopeus harrisii***	**Yes**	HELCOM/OSPAR
78	*Sargassum muticum*	No	Jensen 2013
79	*Skistodiaptomus pallidus*	No	AQUANIS
80	*Spartina townsendi var. anglica*	No	Jensen 2013

	SPECIES NAME	Included in Case Study?	SOURCE
81	*Synidotea laticauda*	No	AQUANIS
82	*Telmatogeton japonicus*	No	AQUANIS
83	*Thalassiosira punctigera*	No	AQUANIS
84	*Undaria pinnatifida*	No	HELCOM/OSPAR

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